

NOTES de RECHERCHES

HOLOCENE GLACIOLOGICAL CONDITIONS,
SOUTHWEST YUKON

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ABSTRACT

Glaciation of the southwest Yukon during the Holocene was dominated by the St. Elias Icefield and, its large outlet glaciers and by smaller ice caps and glaciers in the Donjek and Kluane Ranges. There have been a number of fluctuations of these glaciers through the Holocene as a result of climatic response differences between the large and small icefields and the superimposition of surge events on the general fluctuation pattern. The pattern of glacial advances support multi-fluctuation models for the Holocene however, paucity of datable material has precluded a determination of synchronicity or non-synchronicity of the fluctuations.

INTRODUCTION

The southwest Yukon Territory was extensively glaciated during the Pleistocene from an ice source covering the St. Elias Mountains (Muller, 1967). Various aspects of the glacial history have been discussed in the literature since the 1950's (Sharp, 1951; Bostock, 1952; Muller, 1958, 1967; Krinsley, 1965; Denton & Stuiver, 1967; Fahnestock, 1969; Rampton, 1969, 1981; Kristjansson, 1980), mainly on the basis of Hypsithermal/Neoglaciation type models. It is clear, however, that there is a need for a reinterpretation of the Holocene history in the light of recent theories of glacier fluctuation and the effects of glacier surges (Denton and Karlen, 1973; Karlen, 1979).

By the end of the Pleistocene, the area north and east of the Shakwak Trench had been deglaciated with the possible exception of a few cirque glaciers in ranges such as the Ruby Range (Fig. 1). Southwest of the Shakwak Trench the major icefield was confined to the higher elevations in the St. Elias Mountains on the Yukon Alaska border. The St. Elias boundary ranges were the location of numerous small ice caps. Evidence is known from three glaciers emanating from these ice sources to demonstrate patterns of the Holocene glaciological history. The Donjek Glacier, on which the main emphasis of the paper will be placed, is a large outlet glacier of the St. Elias Icefield. It occupies a tributary valley terminating at an elevation of about 1,000 m.a.s.l. at its confluence with the Donjek Valley. The large lobate terminus of the glacier constricts the Donjek River to a course along the eastern valley wall and has, on occasion, dammed the river in the upper Donjek Valley. A number of surge events have been dominated over the last forty years, but there is no evidence of similar occurrences during the Holocene. The surges have not resulted in long terminus advances. The Kaskawulsh Glacier, another of the large outlet glaciers from the St. Elias Icefield, terminates at the difffluence of the Slims River Valley and the Kaskawulsh River Valley (Fig. 1) at an elevation of 900 m.a.s.l. It displays no evidence of surge occurrence in its recent history but is unusual in the fluctuations of its main drainage between the two valleys. The third site, the Grizzly Creek Glacier, is also non-surgng. It emanates from a small ice cap in the Donjek

Range and terminates at 1,900 m.a.s.l. at the head of a small, steep, alpine valley which is dominated by mass movement landforms.

The moraines of all three glaciers are ice-cored, a characteristic of most of the glacier systems in the region. The moraines contain evidence for a number of periods of glacier fluctuation in both the pre Neoglacial maximum and post Neoglacial maximum periods. The Neoglacial, which is marked by the absence of the White River Ash (Stuiver et al., 1969), is used as a marker event because it is the only phase which can be dated at a number of sites.

HOLOCENE GLACIER FLUCTUATIONS

The development of Holocene glacier fluctuation models has been based on geomorphological evidence and on a series of indicators of climatic trends. The earliest model was based on the concepts of Matthes (1900). The Hypsithermal, a period of climatic amelioration and general glacier retreat was followed by the Neoglacial readvance (Little Ice Age). Over the last two decades evidence has been presented for a model based on a series of glacier advances during the Holocene. Denton and Karlen (1973) postulated four main advances, a concept which Kristjansson (1980) applied to the Grizzly Creek site. Denton and Karlen also proposed many smaller time scale, variations with peaks at A.D. 1596 - 1620, 1640 - 1643, 1670 - 1680, 1720, 1740 - 1750, 1770 - 1783, 1816 - 1825 and 1840 - 1850 in the Alps. The periodic occurrence of surges superimposed on such oscillations would be very difficult to interpret in the field. In Scandinavia, after encountering problems of correlation of events between neighbouring basins, Karlen (1979) has proposed a multifluctuation model which was not time synchronous between sites. Similar problems have been encountered in the valleys of the Donjek Range and the Kluane Range of the southwest Yukon (Fig. 1).

It is hypothesised that in the St. Elias area the larger outlet glaciers exhibit evidence for a number of Holocene advances. In addition the smaller ice caps produced by the late Pleistocene deglaciation would be more sensitive to short term fluctuations in climate which may not impact on

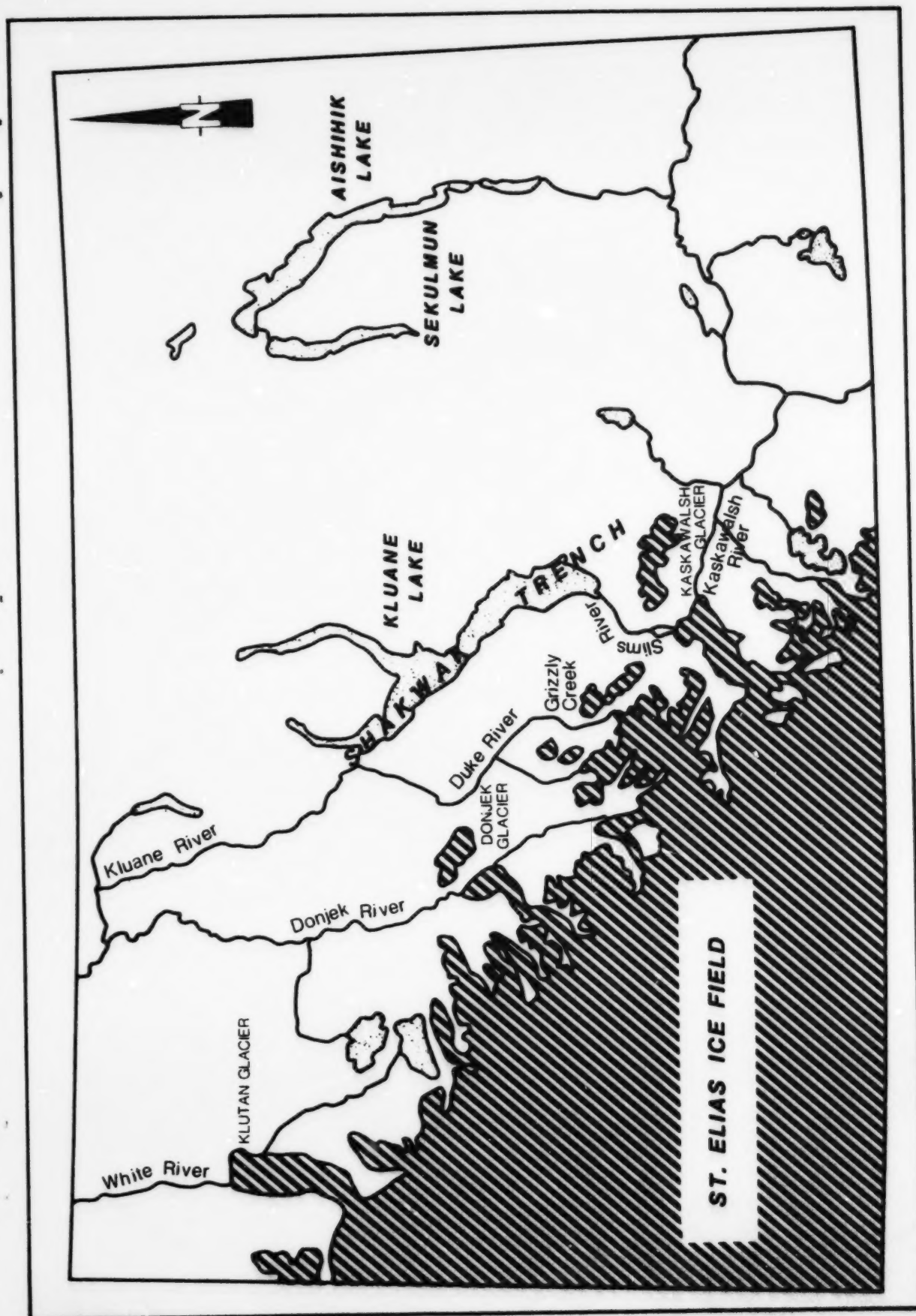


Fig.1. Location map of sites studied in southwest Yukon.

palaeoclimatic indicators. The short term fluctuations may have produced variable patterns of accumulation and ablation on the local ice caps resulting in more complex glacier responses. A large number of dates would be required to analyse the fluctuations because of the complex oscillations which can be documented in the field.

This paper uses the example of the Donjek Glacier, with reference to the Kaskawulsh Glacier and the Grizzly Creek Glacier, to demonstrate variable Holocene conditions and the superimposed effect of glacier surging.

PRE-NEOGLACIAL HOLOCENE FLUCTUATIONS

Johnson (1972) postulated an advanced Hypsithermal position of the Donjek Glacier on the basis of a major lateral moraine on the west side of the valley and the highly denuded remnants of a moraine downvalley. In view of the magnitude of flood events from the ice dammed Donjek Lake calculated by Clarke (1980), it is probable that much geomorphological evidence downvalley would have been destroyed. The postulated ice marginal position lies well inside the late Pleistocene limit of the ice as proposed by Muller (1967). Although the position could correlate with one of the four advances in the Denton and Karlen (1973) model, no means of dating the event has been found in the field.

Denton and Stuiver (1966) assigned a Neoglacial age to the main moraine system (Fig. 2). The conclusion was based on radio carbon dates of 290 ± 80 B.P. (Y1484) and 230 ± 80 B.P. (Y1485) from a tree stump situated on the distal side of the moraine. The origin of this tree is a problem. Given the direction of ice flow the tree could not have been derived from the valley margins. However, the advance of the glacier over an already well vegetated surface, probably an earlier moraine, would account for its presence. Mapping of the outer part of the moraine has revealed the presence of a denuded older deposit which corresponds to a pre-Neoglacial position of the glacier. For the Grizzly Creek Glacier Kristjansson (1980) has demonstrated a close coincidence of ice frontal positions between the Neoglacial and an older advance. He assigned this older moraine to the 2,800 yr event



FIG.2. The Donjek Glacier terminal moraine. View looking west from 1,000 m. Note early Holocene moraine in the upper centre of photograph.

proposed by the Denton and Karlen (1973) four phase model. The evidence for an older age for part of the Donjek moraine complex is both botanical and geomorphological. Portions of the distal edge of the moraine have a more developed vegetation community. For example, a moraine remnant isolated by the Donjek River close to the valley side (Fig. 3 in the upper left corner) is populated by a nature spruce colony. The tree dated by Denton and Stuiver most probably comes from this surface. The geomorphological evidence is the morphological contrast between the washed surface on the distal side of the moraine and the main ridge crest, apparent on the left side of Fig. 3, and mapped in Fig. 4. The Donjek Glacier has, therefore, at least two earlier Holocene positions.

This indication of a multi-age moraine of the Donjek Glacier prompted a re-evaluation of the Kaskawulsh moraine (Fig. 5) which had also been interpreted as the extreme distal section of a neoglacial advance. The moraine has a complex history, character aged by younger deposits superimposed over older ice marginal sediments, as is the case with the Donjek Glacier. High denudation rates, demonstrated by the occurrence of lacustrine silts on the ridge crests, have modified much of the original morphology (Fig. 6). Kristjansson's study of Grizzly Creek (1980) concluded, that: "The stratigraphy and chronology of the Neoglacial drift sequences ... indicates that two phases of Holocene glacier advance are represented in Grizzly Creek Valley". He proposed that these correlate with the Neoglacial and an earlier Holocene position. At all three sites, therefore, there is evidence for glacier fluctuations during the Holocene prior to the Neoglacial.

A major impact of the Donjek Glacier at its Holocene advance positions was the damming of the Donjek River and the formation of a lake in the upper part of the Donjek Valley. Standline sequences can be traced over 6 km upvalley from the terminus and have been interpreted as evidence of a number of filling and drainage events of the lake (Clarke, 1980). The drainage events have been shown to have been catastrophic subglacial flows which have incised the course of the Donjek River into a bedrock gorge. Below this section there is an extensive flood plain pitted with large bedforms which Clarke (1980) has used to calculate the maximum flow rates during drainage of



FIG.3. The Donjek Glacier moraine illustrating the progression from distal pre-Neoglacial to proximal recent surge surfaces.

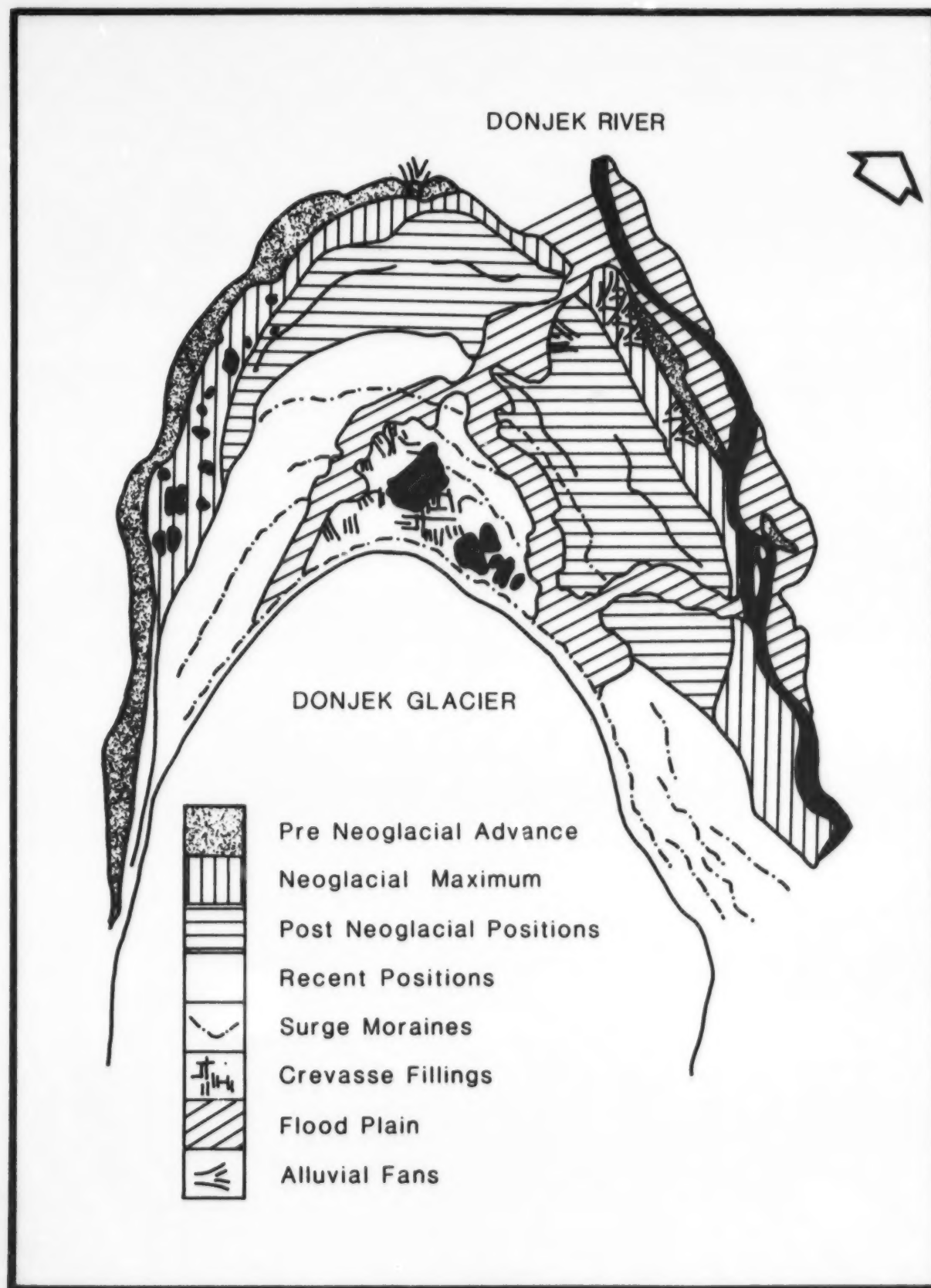


FIG.4. Map of Donjek Glacier moraines identifying components of different ages.

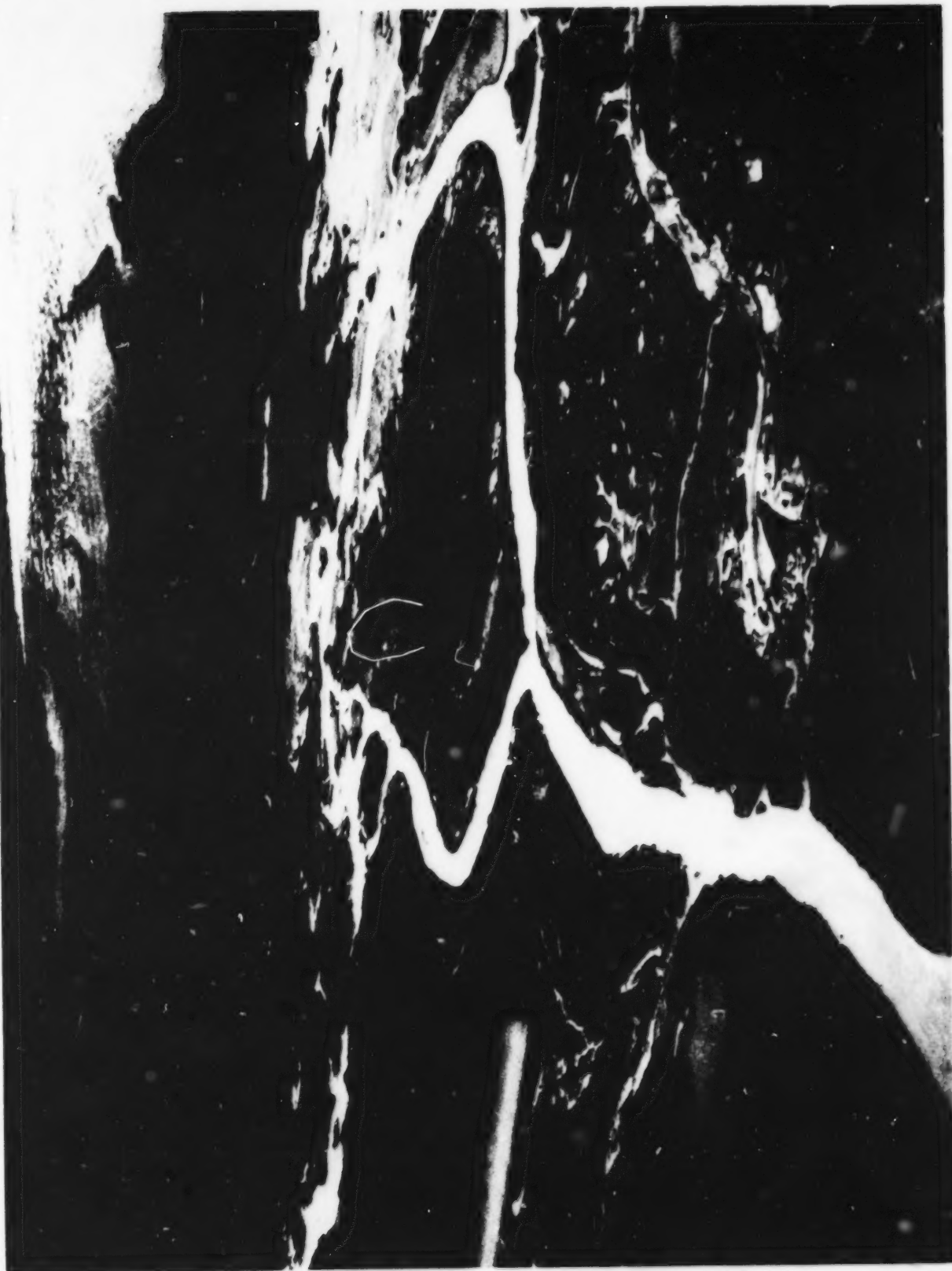


FIG.5. Kaskawulsh Glacier moraines looking south from 500 m. Note the multi-age main ridge (bottom of photograph) and the post-Neoglacial termini to the right centre.



FIG. 6. Highly denuded Neoglacial moraine of the Kaskawulsh Glacier. The pre-Neoglacial surface is visible to the left centre of the photograph.

the lake. The catastrophic drainage events would have been sufficient to obliterate glacial landforms downvalley. The possibility of re-formation of the lake, and the potential for future catastrophic drainage events, have been researched in detail (Clarke, 1980; Young, 1977) because of its implications for pipeline construction across the Donjek River at the Alaska Highway crossing. The lakes have been correlated to surges. However, during recent surges the river has maintained its course and it is postulated that the short time frame surge events may not provide a sufficient ice barrier to dam the river. The sequence of lake events would correlate with the non-surge Holocene advances of the glacier in the pre-Neoglacial (discussed above) and in Neoglacial and recent periods (discussed below).

NEOGLACIAL MORAINES

The moraines, as they appear today, were shaped by the Neoglacial advance into the earlier Holocene moraine. Some deposition by past Neoglacial fluctuations occurs on the proximal side of the moraine. The north west part of the Donjek moraine (Fig. 2 and Fig. 7) is composed of a number of ridges and numerous small ponds occur in closed depressions. The density of vegetation cover progressively decreases from the distal to the proximal side. In Fig. 7 colonisation varies from 90% on the distal side, with willow (Salix reticulata) and poplar (Populus balsamifera) dominant but some spruce (Acea mariana) up to 90 years in age, to less than 10% on the proximal side which is colonized by lichens and individual plants such as Cushion Hawks Beard (Crepis nana). There is thus a progression from the well vegetated outer ridges to the unvegetated areas of kames and push moraines produced by recent glacial activity. The formation of the moraine was probably similar to the events observed between 1970 and 1974 where debris accumulation on low angle terminus slopes produced a series of moraines with the slow retreat of the glacier terminus.

In contrast, the north of the moraine complex represents a relatively stable glacier terminus with a progression from a fluvioglacially washed distal side to a proximal side dominated by ice stagnation (see left centre Fig. 3).



FIG.7. Multi-fluctuation ridges of the northwest section of the Donjek Glacier moraine.

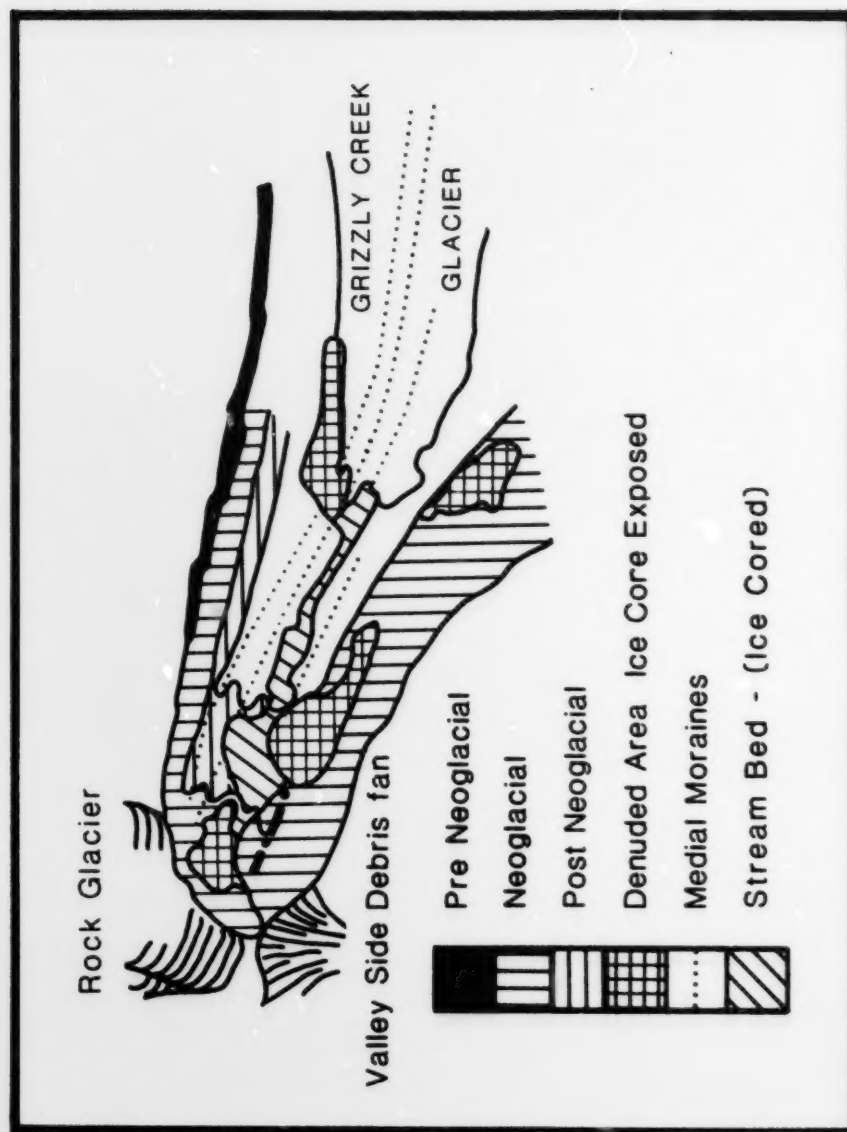


FIG.8. Geomorphological map of the Grizzly Creek Glacier moraine.

The moraine complex consists of a sequence of till, fluvioglacial and glaciolacustrine sediments 2 - 4 m thick overlying stagnant glacier ice. Recent surge activity or meltwater undercutting has exposed the ice core and produced rapid degradation (Johnson, 1971). Slower degradation processes are due to slipping on the ridges producing tension cracks and some mudflows and slumps particularly along the shore of ponds (Johnson, 1971).

The moraine of the Kaskawulsh glacier has been heavily degraded due to ice-core melt, but is relatively simple compared with the Donjek Glacier moraine and indicates a more stable ice front at this time. The same simplicity of form is also apparent at the Grizzly Creek Glacier (Fig. 8). The complexity of the Donjek moraine may be due to the superimposition of the effects of surging on the general advance of the Neoglacial. In the lower right of Fig. 3, on the proximal side of the main ridge, a series of push moraines are very clearly shown. The structure of these ridges is very similar to that of the recent surge moraines which are visible in the upper right of the figure. It is hypothesised that surges have been a characteristic of the Donjek Glacier at least since the waning of the Neoglacial advance.

POST NEOGLACIAL FLUCTUATIONS

The post Neoglacial fluctuations of the three glaciers have followed the same pattern. At all three sites there are indication of two terminus positions. This is most clearly shown by the Kaskawulsh Glacier (Fig. 5) and the Grizzly Creek Glacier (Fig. 8) and is less apparent at the Donjek Glacier (Fig. 4). It is tempting to assume that these fluctuations were time-synchronous, but in view of hypotheses of non synchronicity of events (Karlen, 1979) and the absence of ways to date most of these moraines, they can only be used to support a multifluctuation model.

At the Donjek Glacier the moraines contain deformed glacio-lacustrine deposits demonstrating a push mechanism which imply that the moraines were produced by readvance. In Grizzly Creek, deformation structures are absent and the moraines are composed of ice contact deposits indicating formation at a stable ice front during the general retreat from the Neoglacial maximum.

Krinsley (1965) documented the post Neoglacial maximum moraines at the Kaskawulsh and Klutlan Glaciers and he proposed dates of 1880-1905 for the active phases. The Grizzly Creek Glacier and the Kaskawulsh Glacier have been retreating since the most recent of these moraines was formed. The Donjek Glacier is still experiencing periodic surge events and the fluctuations of the glacier since 1935 have been documented photographically by Dr. W.A. Wood, Dr. A. Post and since 1970 by the author. During this period a number of surge events have been recorded which have produced push moraines. These rarely exceed 5 m in height and frequently are cored by glacier ice sheared up from beneath the outwash deposits and till at the glacier terminus. The trend has been one of progressively less extensive advances of the glacier during each successive surge. During the quiescent phases a number of minor depositional landforms are produced which, because of their pattern and absence of structure, have been interpreted as crevasse fillings (Johnson, 1975).

THE EAST AND SOUTHEAST SECTIONS OF THE DONJEK GLACIER MORaine

The detailed record of the glacier history preserved in the moraines to the north and west is absent in other sections of the terminus due to the repeated ploughing effect of the glacier surges and the activity of the lake drainage events.

CONCLUSION

There are five major conclusions which can be drawn from these studies of the Donjek, Kaskawulsh and Grizzly Creek Glaciers. First, all of these glaciers demonstrates two or more Holocene advances and, as the glaciers represent a spectrum of conditions (large outlet surging glacier, large outlet non-surging glacier and small non-surging glaciers), it can be postulated that in the southwest Yukon the Holocene was a period of variable glaciological conditions. Second, at all three sites the Neoglacial maximum advance reached approximately the same position as an earlier advance. This may correlate with Denton and Karlen's concept of an advance at about 2,800 B.P. but no dates are available to verify the hypothesis. Third, surge events are superimposed on the regional fluctuations making interpretation very difficult

particularly if a model of frequent minor fluctuations is considered. Fourth, there is evidence for surge occurrence since the maximum of the Neoglacial but no evidence for surge occurrence throughout the Holocene. The common occurrence of surges at present would strongly suggest that they have occurred frequently in the past as there is no reason to suppose that present conditions are unique. If surges were common throughout the Holocene and the Pleistocene caution must be applied in the interpretation of all glacial deposits and the correlation of events between sites. Fifth, it is hypothesised that fluctuations of the glacier and not the surge events may have been responsible for the damming of the Donjek River. This interpretation changes the calculation of catastrophic lake drainage risks to pipeline and transport facilities in the lower Donjek Valley.

In summary the Holocene glacial history of the southwest Yukon is far more complicated than many of the earlier models have proposed due to variable glacial response with the possibility of superimposition of glacier surge events.

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